ESD-TR-67-105

MTR-389

STUDIES IN DISPLAY SYMBOL LEGIBILITY

Part XVII. The Legibility of the Lincoln/MITRE Font on Television

APRIL 1967

D. Shurtleff

Prepared for
DEPUTY FOR COMMAND SYSTEMS
COMPUTER AND DISPLAY DIVISION
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 512C
Prepared by
THE MITRE CORPORATION
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FOREWORD

This report is one of a series describing symbol legibility for television display. Additional information on this topic may be found in the following reports: "Studies of Display Symbol Legibility: The Effects of Line Construction, Exposure Time, and Stroke Width," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-249, February 1963; "Studies of Display Symbol Legibility, II: The Effects of the Ratio of Width of Inactive to Active Elements Within a TV Scan Line and the Scan Pattern Used in Symbol Construction," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-440, July 1963; "Studies of Display Symbol Legibility, III: Line Scan Orientation Effects," by B. Botha, D. Shurtleff, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-138, May 1966; "Studies of Display Symbol Legibility, IV: The Effects of Brightness, Letter Spacing, Symbol Background Relation, and Surround Brightness on the Legibility of Capitol Letters," by D. Shurtleff, B. Botha, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-134, May 1966; "Studies of Display Symbol Legibility, V: The Effects of Television Transmission on the Legibility of the Common Five-Letter Words," by G. Kosmider, The MITRE Corp., Bedford, Mass., ESD-TR-65-135, May 1966; "Studies of Display Symbol Legibility, VI: Leroy and Courtney Symbols," by D. Shurtleff, and D. Owen, The MITRE Corp., Bedford, Mass., ESD-TR-65-136, May 1966; "Studies of Display Symbol Legibility, VII: Comparison of Displays at 945- and 525-Line Resolutions," by D. Shurtleff and D. Owen, The MITRE Corp., Bedford, Mass., ESD-TR-65-137, May 1966; "Studies of Display Symbol Legibility, VIII: Legibility of Common Five-Letter Words," by G. Kosmider, M. Young, and G. Kinney, The MITRE Corp., Bedford, Mass., ESD-TR-65-385, May 1966; "Studies of Display Symbol Legibility, IX: The Effects of Resolution, Size and Viewing Angle of Legibility," by D. Shurtleff, M. Marsetta, and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-65-411, May 1966; "Studies of Display Symbol Legibility, X: The Relative Legibility of Leroy and Lincoln/MITRE Alphanumeric Symbols," by D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-115, August 1966; "Studies of Display Symbol Legibility, XI: The Relative Legibility of Selected Alphanumerics in Two Fonts," by G. Kinney and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-116, August 1966; "Studies of Display Legibility, XII: The Legibility of Alphanumeric Symbols for Digitalized Television," by G. Kinney, M. Marsetta, and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-117, August 1966; "Studies of Display Symbol Legibility, XIII: Studies of the Legibility of Alphanumeric Symbols in the BUIC Symbol," by G. Kinney and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-302, August 1966; "Studies in Display Symbol Legibility, XIV: The Legibility of Military Map

Symbols on Television" by M. Marsetta and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-66-315, September 1966; "Studies of Display Legibility, XV: Relative Legibility of Leroy and Teletypewriter Symbols," by G. L. Bell, The MITRE Corp., Bedford, Mass., ESD-TR-66-316, September 1966; and "Studies of Display Legibility, XVI: The Legibility of Teletypewriter Symbols on Television," by G. L. Bell, The MITRE Corp., Bedford, Mass., ESD-TR-67-104, April 1967.

ABSTRACT

The legibility of standard Leroy alphanumeric symbols was compared with that of a new font, the Lincoln/MITRE, on a television monitor at resolutions of 8, 10, 12 and 14 lines per symbol height. The new font was not superior in legibility to the Leroy font at any of the values of resolutions tested. While the findings for the new font were negative, insights were gained about how to improve symbol design for more legible television displays. It was recommended that these new design techniques be evaluated in future work on television displays.

REVIEW AND APPROVAL

This technical report has been reviewed and is approved.

CHARLES A. LAUSTRUP, Colonel, USAF
Chief, Computer and Display Division

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SECTION I

INTRODUCTION

There is a need to conduct comparative studies of different fonts for developing standards to guide the designer and manufacturer of display equipment to select the most legible symbols. The present study tried to select a better font for television use by studying the relative legibility of standard Leroy symbols and a set of improved symbols (Lincoln/MITRE) on a television monitor. An improved symbol font may be expected to aid television legibility in either one of two ways, or both, by lowering the minimum number of scan lines per symbol height required for a high accuracy of identification, or to produce faster identification times at previously established minimal values of symbol resolution (10 to 12 lines per symbol height, see references 2, 3, 8 and 9).

A set of alphanumerics which might best serve as a standard would retain good legibility when displayed on any display such as a shaped-beam or slewed-beam cathode ray tube, a high speed printer, an office typewriter, a television monitor and so on. Work on the development of a universally legible font was started several years ago and, in part, continued some earlier work at Lincoln Laboratory. Essentially, this work involved refining a set of symbols originally designed by Mackworth. The history of the development of this font is described in more detail elsewhere.[5]

The latest version of this font called Lincoln/MITRE (L/M) is shown in Figure 1. In a recent study[4] the L/M font was compared with the Leroy font (Figure 1) which is a standard lettering style used extensively in commercial art and advertising. The results of the study showed that subjects made fewer errors identifying tachistoscopically presented L/M symbols than identifying Leroy symbols at each of several values of brightness contrast ratios, ranging from 4:1 to 10:1.

While the work to date with the L/M font is encouraging, there is a need to conduct additional evaluations of this font before it may be recommended as a standard for use in other display applications. Furthermore, the tachistoscope study indicated that some additional improvements might be made in the legibility of L/M symbols by changes in the geometry of those symbols which the subjects mis-identified most frequently. However, before any additional changes in symbol design were made, it seemed desirable to collect more data on inter-symbol confusions when the L/M font is tested in other kinds of displays.

Since the legibility of televised symbols has been a major and continuing interest at MITRE, it seemed reasonable to extend the evaluation of the L/M font by comparing it with the Leroy font on a television monitor. Television represents a unique problem in symbol design because of the way in which the symbols are constructed and displayed. There are two major characteristics of television which influence symbol geometry; the cutting up of symbols by the active lines of the television raster, and the "on-

Figure 1. Top: Leroy Font - Bottom: Lincoln/MITRE Font

off" characteristics of the scanning element. The first characteristic affects symbol geometry by deleting selected parts of the sumbol, while the second characteristic may affect symbol geometry by smearing, which is caused by the lack of a sharp "on-off" response of the scanning element in horizontal transitions from light to dark areas. Both of these characteristics, the cutting up and the smearing of symbols, are shown clearly in Figure 2 where photographs of selected televised symbols at 10 lines are presented.

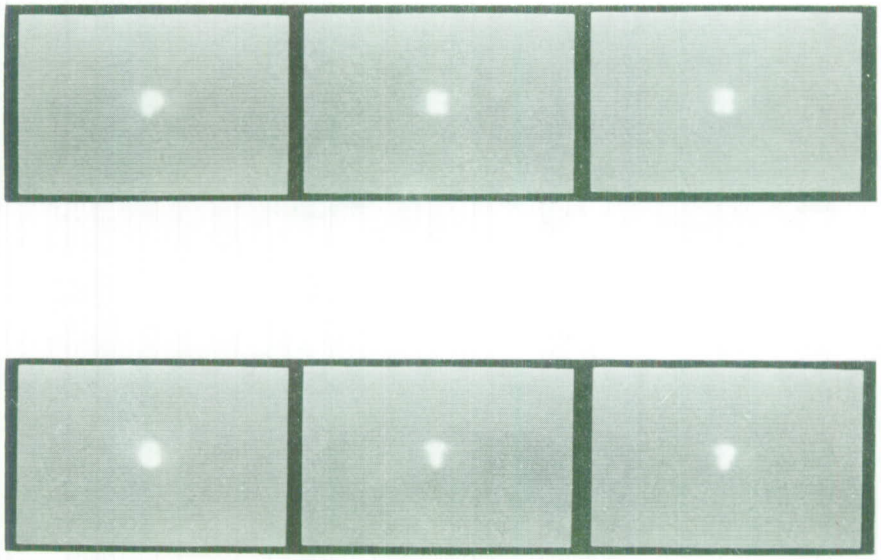

Figure 2. Symbols Resolved by Ten Scan Lines.

Previous attempts to develop a font uniquely suited to television have failed.[7,8] In each case, the improved font was no better than standard Leroy symbols. In the present study, the Leroy font was compared with the L/M font at symbol resolutions of 8, 10, 12 and 14 lines per symbol height. The results showed no marked superiority of L/M symbols over Leroy symbols at any of the resolutions studied. As in previous studies,[2,3,8,9] legibility for both fonts was greatly impaired for resolutions below 10 lines per symbol height. While the findings for the L/M symbols were disappointing, the results provided some new insights into other, and hopefully more fruitful techniques for improving the design of symbols for television displays.

SECTION II

METHODS

SUBJECTS

The subjects were 4 MITRE employees who had 20/20 near and far acuity, normal color vision, and no marked phoria.

TELEVISION EQUIPMENT

The television equipment and manner of presenting symbols to each subject is described in detail in a previous report[1] and only a brief description is given here. The symbols were projected onto a translucent screen which was mounted on a modified Motion Analyzer. The symbols were picked up by a 945-line General Precision camera (Model 820) and shown to the subject on a Conrac(Model CQE 14/945) 14-inch video monitor. The camera-to-screen distance was arranged to obtain the desired line resolution, and the subject-to-monitor distance was arranged to maintain an angle of subtense at the eye of 16 minutes of arc. The subject initiated the exposure of a symbol by depressing a button. The exposure of the symbol was ended when the subject made his verbal identification. The subject was instructed to make his identifications as quickly and accurately as possible. The time required to identify each symbol, and the symbol named, were recorded.

THE L/M AND LEROY SYMBOLS

The symbols were photographed on 35 mm film strips. Each strip contained 180 symbols of a given font with the 36 symbols appearing five times each. The average symbol width for the two fonts was 3/4 of the symbol height. The two fonts had a ratio of stroke-width to height of 1/6. It was necessary to modify the standard Leroy Ø and I in order to differentiate the Ø from the letter O, and the numeral 1 from the letter I.

The sequence of symbols on the film strip was determined by a table of random numbers. A stepping switch controlled the advance of the film through the film projector and provided a number of different symbol sequences, which helped to prevent the subjects from memorizing the letter sequences.

EXPERIMENTAL DESIGN

Each subject identified symbols in both fonts at each of the four values of resolution (8, 10, 12 and 14 lines). The subjects viewed one font at all resolutions before being presented the other font, two of the subjects seeing Leroy first and the other two seeing Lincoln/MITRE first. The two subjects seeing Leroy first were presented the resolutions in two different orders which were determined by a table of random numbers. These same sequences of resolutions were used also for the two remaining subjects who started with the L/M font. When the subjects were

switched to the alternate font, two new orders of resolutions were made up with a table of random numbers. Each subject seeing the Leroy font viewed one of the new sequences and these same sequences were used for the two subjects who saw the L/M font (see Table I).

Table I

Sequence of Resolutions for Each of the Four Subjects Viewing Leroy and Lincoln/MITRE fonts

	LEROY				LINCOLN/MITRE			
S_1	12	10	8	14	8	14	10	12
S_2	8	10	14	12	12	14	8	10
	LINCOLN/MITRE				LEROY			
S_3	12	10	8	14	8	14	10	12
S_4	8	10	14	12	12	14	8	10

Each of the subjects made a total of 180 symbol identifications (5 per symbol) for each font at each of the 4 resolutions. Before each series of sessions with a given font, the subjects were given practice in identifying the symbols making up that font. The practice session included 180 identifications, 5 for each symbol of the font. These symbols were shown on the television monitor and were resolved by 60 active

lines per symbol height. During practice any errors made by the subject were corrected by the experimenter and errors rarely occurred during practice.

CHARACTERISTICS OF TELEVISED SYMBOLS

The active lines in the symbols had an average brightness of approximately 20 fL and a background brightness (to one side of the symbol) of approximately 2 fL as measured by a Spectra Brightness Spot Meter. The procedure followed in adjusting the television equipment before each experimental session is described by Bell.[1]

SECTION III

RESULTS AND DISCUSSION

The percentage of identification errors for L/M and Leroy symbols at each of 4 values of resolution are shown in Figure 3; the identification speed for these two fonts at the same values of resolution are shown in Figure 4. As Figures 3 and 4 indicate, there were no marked differences between the two fonts in either accuracy or speed for any of the resolutions studied. The speed and accuracy of symbol identification for each subject are presented in Tables II and III. From Tables II and III it is evident that none of the differences between fonts were very large and statistical analysis revealed no significant differences in these data. Even the relatively large mean differences in identification time for the two fonts at a resolution of 8 lines was not statistically significant.

The effects of decreases in resolution on speed and accuracy of symbol identification for both fonts is similar to that reported in many previous studies.[2,3,8,9]

Two conclusions follow from these data: (1) Televised L/M symbols are not superior in legibility to televised Leroy symbols, and (2) a minimum resolution of 10 lines per symbol height is required for a 90 percent or better accuracy of identification.

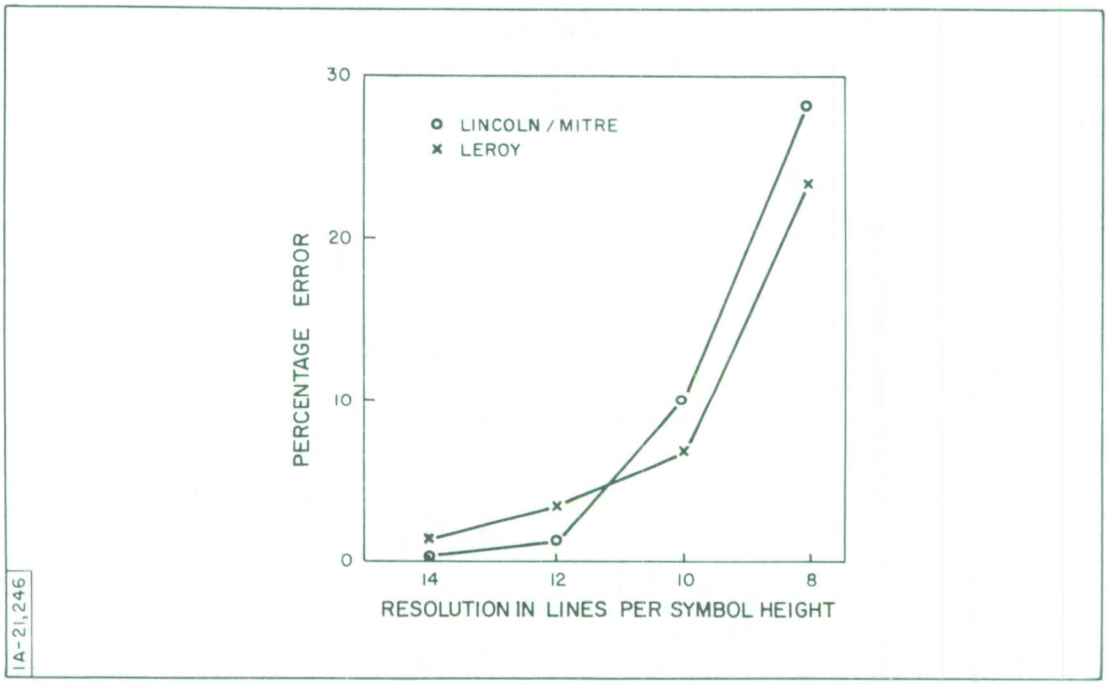

Figure 3. Percentage Error for L/M and Leroy Symbols

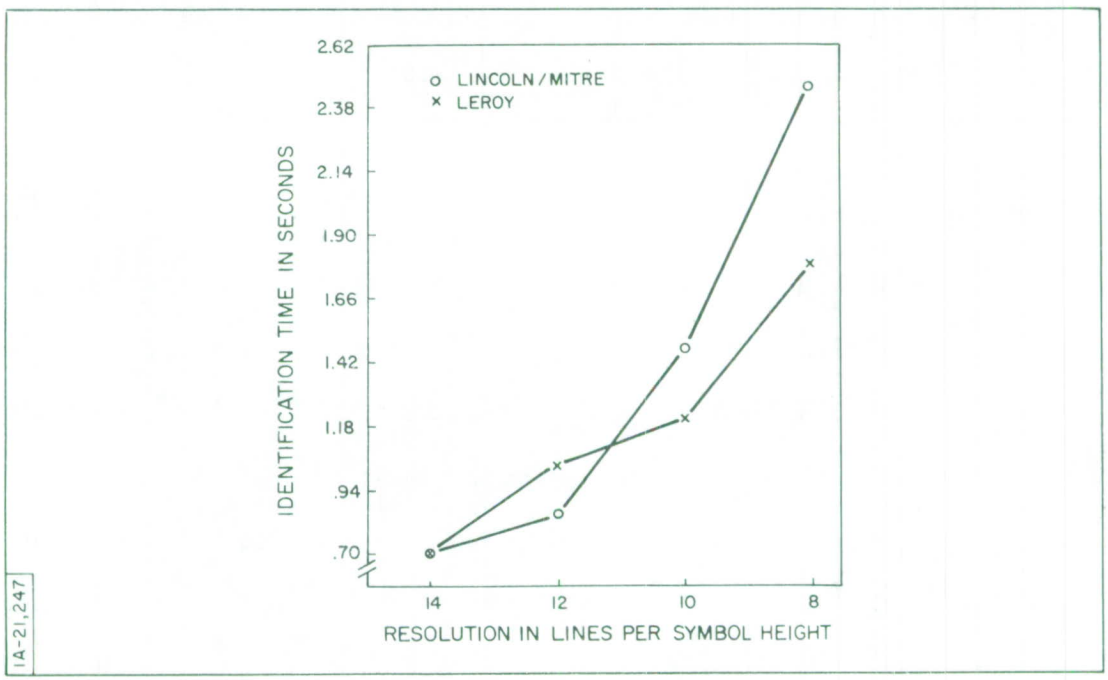

Figure 4. Identification Time for L/M and Leroy Symbols

Table II

Percentage Error for Each of Four Subjects

	Resolution in Lines Per Symbol Height							
	14		12		10		8	
	L/M	Leroy	L/M	Leroy	L/M	Leroy	L/M	Leroy
Subjects 1	0	1	0	6	2	7	8	14
2	1	3	2	2	8	9	36	42
3	0	0	3	3	12	5	23	17
4	0	1	0	3	18	7	46	22
Mean	0.25	1.25	1.25	3.50	10.00	7.00	28.25	23.75

INTER-SYMBOL CONFUSIONS

The particular symbols which had the highest concentration of errors were similar for the two fonts at resolutions of 8 and 10 lines. The only notable difference between the two fonts was at a resolution of 12 lines where there was no confusion among the L/M symbols while the B, 8, Q, O, G and 6 of the Leroy font continue to be major sources of error. The absence of errors for the L/M font and the presence of

Table III

Identification Time in Seconds for Each of Four Subjects

	Resolution in Lines Per Symbol Height							
	14		12		10		8	
	L/M	Leroy	L/M	Leroy	L/M	Leroy	L/M	Leroy
Subjects 1	0.65	0.69	0.76	1.49	1.01	1.32	2.93	1.41
2	0.63	0.69	0.75	0.71	1.08	0.90	1.38	1.50
3	0.54	0.57	0.87	0.71	1.42	0.82	1.63	1.36
4	0.96	0.84	1.04	1.25	2.36	1.75	3.92	2.93
Mean	0.70	0.70	0.86	1.04	1.47	1.20	2.46	1.80

errors for the Leroy font at 12 lines is not too surprising when it is recalled that the L/M font is essentially a refinement of the geometry of a font much like the Leroy.[5] It is noted that by comparing the two fonts (see Figure 1) the geometric refinements include such things as increasing the size of small symbol detail (for example, increasing the length and changing the position of the horizontal bar of the letter G), changing the outline of symbols (for example, changing the upper part of the numeral 8 from a circle to a triangle), and altering the curvature of symbol strokes (for example, changing the curvature of the letter S). The failure of these design changes to aid identification at the lower resolutions is probably related to the fact that small differences in detail and stroke curvature are not resolved sufficiently by the coarse scan structure of the television. Apparently, a scan structure as fine as 12 lines per symbol height is needed before these geometric differences are resolved sufficiently for the subject to be able to detect them and use them in his identifications.

DESIGN OF SYMBOLS FOR TELEVISION

It is clear from the results of the present study and previous studies[7,8] that small changes in detail and curvature of strokes of symbols are not going to improve the legibility of television displays. It appears that two other ways of changing symbols should be evaluated before the search for a better television font is abandoned.

In an earlier study[7] twelve Leroy symbols were revised and tested for legibility on a television monitor. Eleven of these revisions involved small changes in symbol detail, but one revision involved a rather simple design change, that of increasing the width of the letter H from 75 percent to 100 percent of the symbol height. Most of the changes in small detail were not successful, but increasing the width of the H eliminated both the H-called-M and the H-called-N confusions which previously had been major sources of error. The finding suggests that increasing symbol width might be successful with other symbols involved in major confusions on television.

In addition to increasing symbol width, design changes involving a decrease in symbol stroke-width may be successful. Gross changes in symbol design such as increasing the width or decreasing the stroke-width of symbols may be expected to aid television legibility because the discrimination of gross detail is less dependent upon the fineness of the scan structure than is discrimination of small symbol detail.

Furthermore, increasing the width or decreasing the stroke-width of symbols may be expected to improve legibility by reducing the amount of horizontal smearing of symbol strokes. Therefore, further work may produce better symbols for television by studying the effects of symbol width and stroke-width.

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DS/dp

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UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
The MITRE Corporation
Bedford, Massachusetts

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
STUDIES IN DISPLAY SYMBOL LEGIBILITY
Part XVII. The Legibility of the Lincoln/MITRE Font on Television

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
N/A

5. AUTHOR(S) *(Last name, first name, initial)*
SHURTLEFF, Donald

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April 1967	25	9

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
AF19(628)-5165	ESD-TR-67-105
b. PROJECT NO. 512C	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	MTR-389

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Deputy for Command Systems, Computer and Display Division, Electronic Systems Division, L. G. Hanscom Field, Bedford, Massachusetts

13. ABSTRACT

The legibility of standard Leroy alphanumeric symbols was compared with that of a new font, the Lincoln/MITRE, on a television monitor at resolutions of 8, 10, 12 and 14 lines per symbol height. The new font was not superior in legibility to the Leroy font at any of the values of resolution tested. While the findings for the new font were negative, insights were gained about how to improve symbol design for more legible television displays. It was recommended that these new design techniques be evaluated in future work on television displays.

DD FORM 1 JAN 64 1473

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